

Project title:

Creating know**L**edge and skill**L**s in **A**dditive **M**anufacturing



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Report on Additive Manufacturing

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Introduction

The increasing growth of Metal Additive Manufacturing (AM) technology is demanding the definition of new professional levels required by industry for personnel working in this area.

CLLAIM project has been performing a research on this topic to get a better overview on the requirements and training contents for the following professional profiles: the European Metal AM Operator, the European Metal AM Specialist, the European Metal AM Designer, the European Metal AM Inspector. This report is a preliminary analysis of the AM market and will serve as a basis to future project developments.

The objective of this report is to provide insight on the strategic relevance of the additive manufacturing technologies in each partner country (Spain, Germany, United Kingdom) as well as to highlight their impact on the different industrial sectors. A combined methodology was applied to the research, encompassing various tools and techniques: performing a desk research, conducting focus group meetings, as well as undertaking local/national sectorial analysis.

Section I – Desk Research- Some relevant observations

This section describes briefly how Additive Manufacturing Industry behaves worldwide, and how it is spread across different countries. Also, it aims to briefly expose the strategy and forecast of the development of the industry on the next couple of years.

Several sectors of the industry are considered under AM development. Additive Manufacturing is revolutionizing industrial competitiveness. Several studies were conducted in this field and they all point to a brighter future. This section of the report aims to give a general overview of the Additive Manufacturing sector and structure its future development so that, in the rest of the project there is an understanding of AM state of art.

In order to develop the knowledge on the AM market some research was conducted. On the “*Additive Manufacturing Industry Landscape 2019: 171 Companies Driving the Industry Forward*” it is settled a Landscape of AM. The following figure illustrates the results obtained with the study.

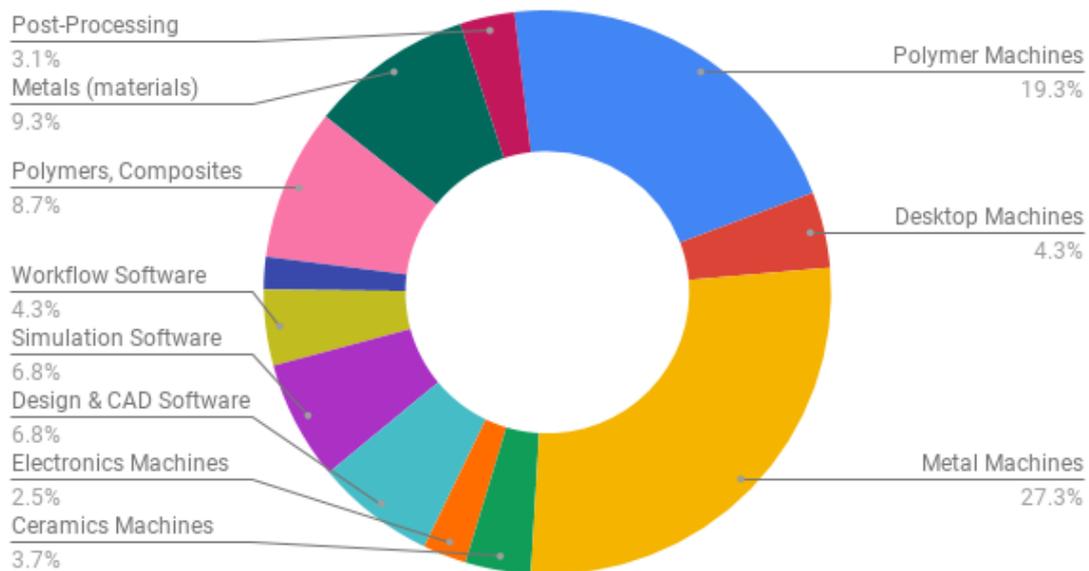


Figure 1 A look at the key segments of the 161 companies featured in the landscape, *The Additive Manufacturing Industry Landscape 2019: 171 Companies Driving the Industry Forward* [1]

As it can be observed in the figure most of the companies that are evaluated in this landscape are producers of Metal Machines and Polymer Machines. Furthermore, a large portion of the Entities work with Metals and a slightly smaller work with Polymers. Therefore, it is validated the necessity of developing a Qualification System for Metal Additive Manufacturing sector and justified the necessity of CLLAIM project. Also, it is

identified a large portion of entities working on software being the most representative the ones working on Design & CAD Software followed by Simulation, these two areas are also very interest to CLLAIM project as they are covered majorly by AM Designer profile. Besides that, it is also interest that a representative portion of this Landscape refers to entities working in Post-Processing, being one area that already has some relevance and will continue to increase in the future. Furthermore, this area of post-processing also interests CLLAIM project professional profiles development.

A summary of the relevance of the areas of interest covered by CLLAIM project: Post-processing, Metals, Metal Machines, Simulation Software and Design & CAD Software areas all interest to CLLAIM project. This represents 53.3 % of AM landscape, which means that CLLAIM project will address a large part of AM market, and it is identified here the areas that concern the professional profiles developed in the project. [1]

Besides that, to get an AM general overview a good report to look upon is the 2018 edition of the Wohlers Report, where it states:

“64 manufacturers of industrial AM systems (those that sell for \$5,000 or more), 19 producers of third-party materials and desktop 3D printers, and 92 service providers worldwide responded to surveys for use in this section. These 175 companies represent more than 100,000 users and customers and provided information based on knowledge of these AM users and customers.” (Wohlers Report, 2018).

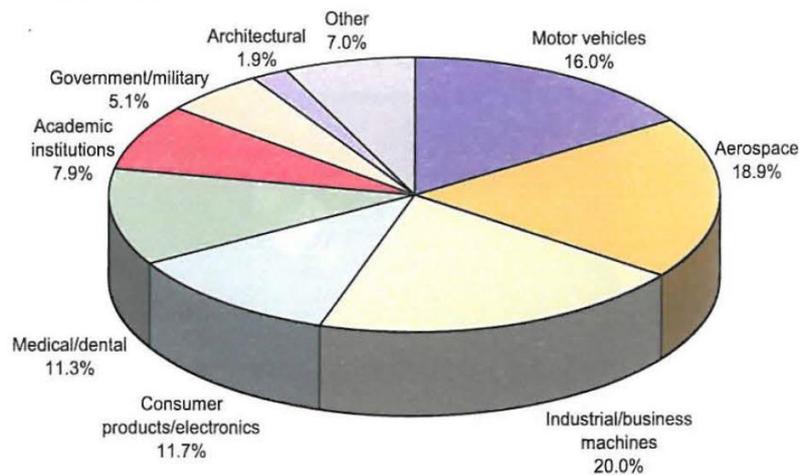


Figure 2 AM applications, Wohlers Report 2018 [2]

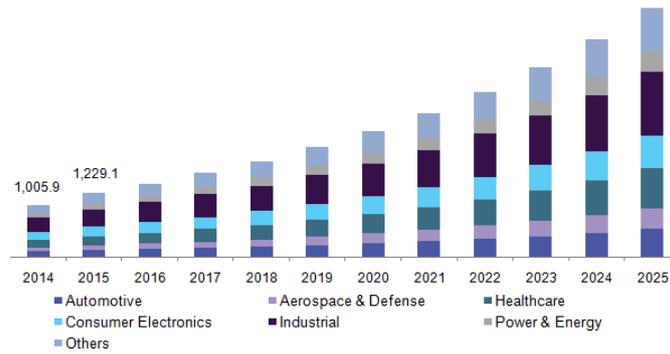


Figure 3 AM applications, Wohlers Report 2018 [2]

The graphics above (figure 2 and 3) give us a full understanding of how AM industry is distributed across the various sectors and the expansion suffered in each sector during the last years as well as an estimation of how it will rise in the next years.

According to the Wohlers Report, the sectors with higher AM coverage are Industrial Machinery, Aerospace 19%, Automotive 16%, Consumer Electronics 11.7%, Health 11.3%.

Furthermore, there is a prediction on how the demand in this major AM sectors will evolve along the next couple of years. The report does not predict an inversion of the percentage relative to each sector in the next 6 years, as it is hard to understand exactly how industry will behave in the future. Although, it predicts that AM demand will double in the next 6 years, which is a major indicator of the relevance of identifying industry skills and developing educational means to tackle those needs.

One of the main indicators used to track AM is the number of industrial with AM systems installed. As shown in figure 2, U.S. leads this classification per country. China, Japan, Germany and United Kingdom have the second, third, fourth and fifth largest installed bases, respectively, of AM systems worldwide. Spain industry ranks 14th worldwide position. This identifies that the consortium countries are well positioned in the AM industry, therefore the relevance of the project partnership. [2]

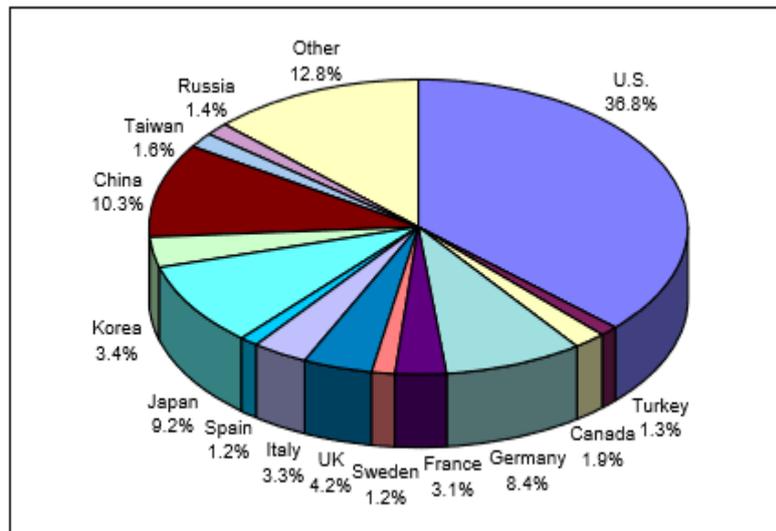


Figure 4 AM systems installed by country from 1988 to 2016, Wohlers Report 2018 [2]

In many industries, a very relevant area of interest is Standards. Standards drive the Industry towards a common sustainable growth. Being Additive Manufacturing an emergent industry Standards can be particularly important furthermore in highly technical industries, such as AM, they provide the foundational element on which the industry might be built. Ongoing efforts to establish AM standards is helping the industry to growth as it defines requirements for production that enhance consistency and guides the market through a sustainable growth. A substantial number of standards has been published.

Although, standards for AM are being developed at a good pace, there can still be found some gap areas. These gaps are concerned with material’s characteristics, process control, AM machine calibration, post-process.

The Qualifications developed in CLLAIM project aim to be as aligned with standards as possible. Therefore, the most relevant presence in the partnership of LLOYDS Register a Certification Body and a very close contact with Standardization Bodies such as

International Organization for Standardization (ISO) and American Society for Testing and Materials (ASTM) is identified as required. [3]

This section of the report also concerns on how additive manufacturing will develop in the future. For that some research was conducted and some results of that research are her illustrated. The following figure represents the prediction of the increase in AM Market for the next 6 years.

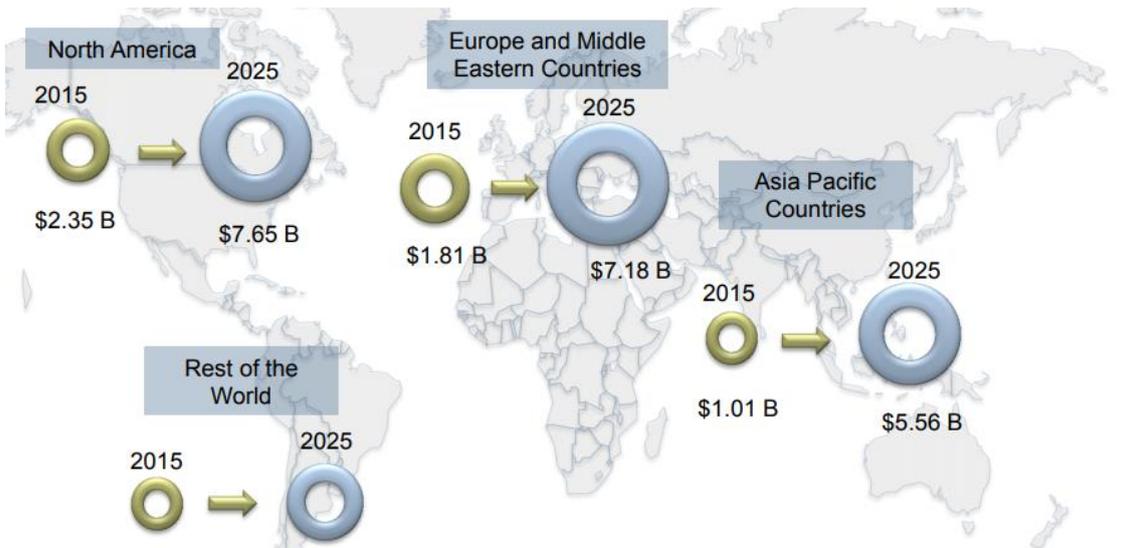
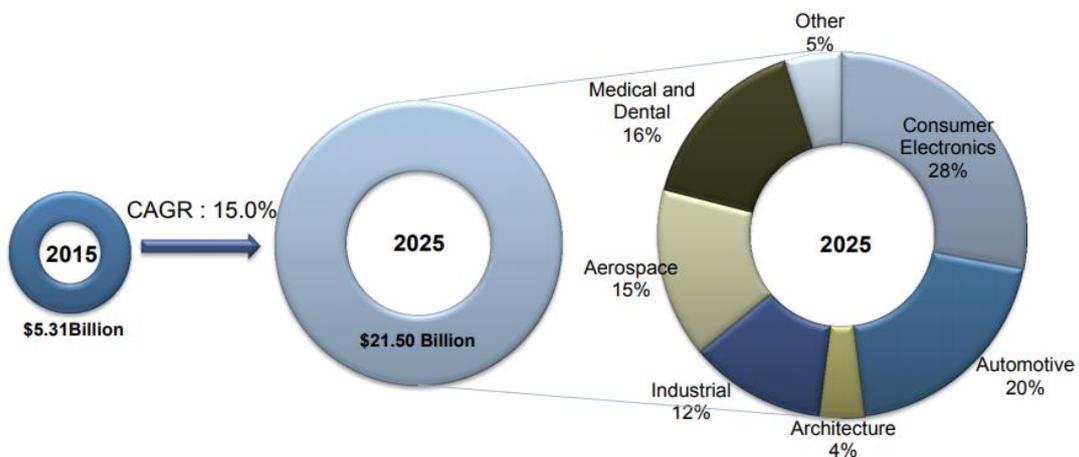


Figure 5 AM Market increase in \$, Global Additive Manufacturing Market, Forecast to 2025 [4]

The figure illustrates a prediction of a representative increase in AM worldwide (4 times bigger in 10 years' timeframe). In Europe, it expected than on 2025 the market reaches 7180 Million Dollars, which represents a significant part of the industry in its globality.

Being this report focused on AM Sectors there is a figure that illustrates the change in Sectors, predicting how they will behave in 2025.



Others include Energy, Construction, Food & Beverage, and others

Source: Frost & Sullivan

Figure 6 AM Sectors 2025, Global Additive Manufacturing Market, Forecast to 2025 [4]

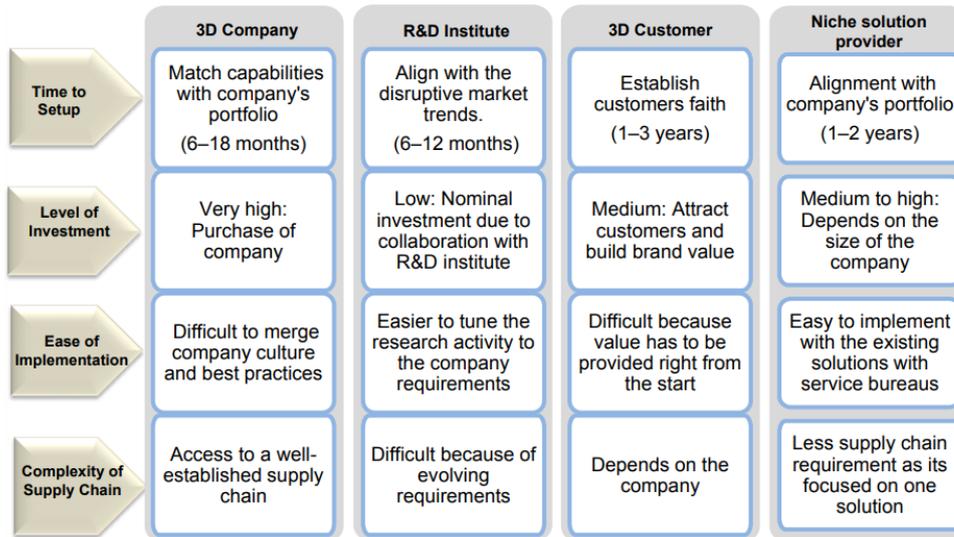
The report “Global Additive Manufacturing Market, Forecast to 2025” concludes that the four major sectors in 2025 will be Consumer Electronics, Automotive, Health and Aerospace. This information is in liaison with the results obtained by the Wohlers report presented previously. Although in liaison the percentual values of the sectors change significantly in 2025. When comparing the values we observe that Aerospace decreases from 19% to 15%; Automotive Sector increases its percentage from 16% to 20%; Health sector increases from 11.3% to 16%; and finally a major finding is that the sector Consumer Electronics will increase exponentially from 11.7% to surprising 28% of the overall market. This representative change on sectors balance alerts the partnership not to focus just on a specific sector. [4]

A final point to look into this chapter is on the strategy that will be undertaken in order to reach a bright sustainable future. The MANUFUTURE Vison and Strategy for 2030 develops some strategies for the Industry. The following figure represents a summary of the strategy for the Industry as a global.



Figure 7 MANUFUTURE Vison and Strategy for 2030, *Report of the ManuFUTURE* [5]

As the figure suggests the Industry will develop towards 5 pillars, and is expected that Additive Manufacturing growth is sustained by them. The pillars represented on the figure are the 5 key aspects that will support the industry into more competitive environment and exponential growth until 2030. After a global vision of the strategy for the all Industry, was conducted research on the strategy specifically for AM. The following figure explains the steps to overcome and lists the actual status of the Additive Manufacturing Industry.



Source: Frost & Sullivan

Figure 8 AM Strategic Explanation, Global Additive Manufacturing Market, Forecast to 2025 [4]

The figure divides evaluation of the AM status into four different levels: Time to Setup, Level of Investment, Ease of Implementation, Complexity of Supply Chain. Separating each one of the levels by 4 different targets: 3D Company, R&D Institute, 3d Customer, Niche solution Provider.

For each one of the components of the matrix it is suggested a plan for the strategy to uptake. With regards to the time required to Setup we can see that the most difficult to implement is to Establish customers faith (evaluated in 1 to 3 years). And for the rest of the targets the time is still quite high with a minimum of 6 to 12 months for Research & Development.

With regards to the level of investment required it is expected a Very High investment for a 3D Company to start. On the other hand, there is needed a low investment for a R&D Institution to start as there are many National and European Investment on this area.

Regarding the ease of implementation, it is difficult for 3D Companies to implement as it represents a change of production paradigm. On the contrast, a Niche Solution Provider has easier access to implement Additive Manufacturing.

Finally, regarding the access to a supply chain, a 3D Company shall need access to a well-established supply chain when comparing to a Niche Solution Provider that will normally only need access to a small part of the supply chain. [4], [5]

In conclusion, this section of the report aimed to give a simple overview on the Additive Manufacturing Market. Further in the report AM Market will be evaluated in more detail with the aid of focus group meetings and an extensive analysis of AM Entities data. Moreover, the results found in this section will be compared with the ones found in the rest of the report, being the following chapters constructed taking into consideration the results found here, aiming to broaden the knowledges here identified as well to validate the results. Furthermore, it is confirmed that the results illustrated here regarding distribution of sectors in the AM market have a big comparison with the ones found at the end of the report.

Section II –Focus Groups Results

Under CLLAIM scope various focus group meetings were conducted by project's Partners and targeted at least one sector being highly influenced by metal AM. The aim was to identify, for each country, the relevance of implementing a European AM Qualification System within the sectors most influenced by metal additive manufacturing technologies. The focus group reported here only represent an initial approach to the industry needs, on further report (D2.1) these methodologies will be carried in more detail by considering the validation of the findings from the surveys.

Representatives from different sectors were invited to share knowledge and experience, allowing Partners to gather an industry-based perception on the matter. Stakeholders were invited to describe the strategic relevance of metal additive manufacturing for their specific sectors (e.g. Automotive, Aerospace, Medical, Consumer Products, Industrial Equipment and tooling, Railway, among others) and give their opinion on how a European Qualification System in Metal Additive Manufacturing could be relevant for them.

This Chapter of the report englobes the results of several focus group meetings conducted on partner's countries.

1. Spain

On this section of the report it will be briefly described the results of the focus group meetings conducted in Spain. The chapter is separated into four topics, considered most relevant for the analysis conducted on this report on AM.

1.1 Companies fit in the sector

Table 1 Companies' sector

Sectors	Companies
1. Aerospace	ACITURRI ADDITIVE MANUFACTURING SLU AIRBUS OPERATIONS S.L.
2. Automotive	NA
3. Industrial Equipment and Tooling	NA
4. Other	NA

1.2 Companies fit in the value chain

Table 2 Companies' Value Chain

Companies	Value Chain					
	Modelling & Design	Materials	Process	Post-Processing	Product	End of Life
Airbus	X	X		X	X	
ACITURRI	X	X	X	X	X	

1.3 Evidences from the focus group meetings

Table 3 Focus Group Results

ORGANISATION	AIRBUS OPERATIONS S.L.	ACITURRI ADDITIVE MANUFACTURING SLU
1. Main sectors served	Aerospace	Aerospace
2. Strategic relevance of metal AM for your main sector(s).	<p>We are currently looking for opportunities to investigate and introduce this technology in our products, growing step by step, being safety our very first priority, starting from low relevant parts to eventually introducing primary structure part.</p> <p>Successful applications must also be business driven as well, so positive economical parameters are also necessary.</p>	<p>Air transport pays special attention to environmental problems, noise and climate change.</p> <p>It is a demand of the aeronautical sector to reduce the weight of airplanes in order to optimize the payload and, at the same time, contribute to having a "clean sky".</p> <p>In the aerospace industry, metallic materials constitute approximately 75% by weight of the materials used in the manufacture of structures, components, mechanisms, etc., of aerospace vehicles. The alloys of aluminum, titanium, chromium, cobalt or nickel, due to their low density, are widely used in the manufacture of components, which constitute approximately 60% of the structure of the aircraft.</p> <p>The application of additive manufacturing, which allows complex geometries eliminating material where it is not really necessary, is ideal to reduce the weight of the components, both structural and motor, while ensuring structural strength in accordance with high and demanding safety standards of the aeronautical industry.</p>
3. Is the creation of a European Qualification System in metal AM relevant for the sector(s)?	<p>I think that overall it will be positive; although in Airbus we are developing our internal qualification processes, being discussed and aligned with the Airworthiness Authorities from the different geographical regions in which our Products operate.</p> <p>We can always take benefit thanks to a previous alignment with</p>	<p>The process of certification of an aircraft is very exhaustive and extends to materials, machines and processes as well as to personnel involved in its manufacture or maintenance.</p> <p>The creation of a "European Qualification Body in Metal Additive Manufacturing" would add value to the aeronautical sector if its intervention could validate the current habilitation processes and not duplicate these processes.</p>

	<p>this European Qualification body in order to facilitate the industrial capabilities of the supply chain.</p>	
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1.4 Further relevant information

ADDIMAT, the Spanish Association of Additive Manufacturing Technologies and 3D, groups together all the players with interests in developing and promoting additive manufacturing technologies. [6] ADDIMAT groups more than 60 companies, which have become increasingly important for the aerospace, biomedicine and automotive industries, among others. Considering their member companies as representative of the Spanish AM ecosystem, it involves:

- **Manufacturers of AM equipment or their components and consumables.** Spain is a global force in machine tool production and export. The sector is characterized by its proprietary technology based on the ongoing research, development and innovation efforts of its companies as well as the continuous collaboration with the numerous technology centres located in the geographical area. In this sense, some machine tool companies are developing solutions adapted to additive manufacturing. Clients and markets are led by the automotive, aeronautical and mould sectors. On the other hand, there are some companies exclusively specialized on the manufacturing and commercialization of 3D printing equipment. This kind of companies are usually small companies of innovation and development of new 3D technologies (e.g. Advanced Production Tools, Tumaker) or distributors of renowned brands (e.g. Grupo Sicnova) with own R&D department. New companies are also emerging focused on the development of filaments or powders for 3D printing (e.g. 3R3DTM, Aubert&Duval).
- **AM printing service providers.** In Spain, there are a number of new companies that focus their activity on the design and part manufacturing of components with own 3D printing means (e.g. Addimen, CITD, Mizar, Optimus 3D, Undo Prototipos). These companies work specially to the aerospace sector (assembly tools, testing prototypes, final parts...) and the medical sector (custom-made implants, personalized anatomical models...). Moreover, mature manufacturing companies specialized in specific sectors such as aerospace or injection moulding have

incorporated 3D printing technologies and began to produce additive manufacturing parts for their customers.

- **Users of AM technologies.** Only 7 companies of the ADDIMAT's association uses AM technologies for own production. It is relevant that two of them (Aciturri and ITP) are leading providers in the aerospace sector. The rest of companies belong to the medical, tooling, automotive, steel and electronic sectors.
- **Dealers and marketing subsidiaries.** As a clear indicator of the increasing activity of the sector, in Spain there are authorised distributors of manufacturing systems, engineering software for product development, raw materials and supplying gases.
- **Universities and R&D centres.** AM industrialization in Spain is supported by a strong research network based on universities and technology centres, which accumulate wide experience on additive manufacturing. Some of them, like Prodintec, Tecnalía or IK4, address AM from a multisectorial point of view. Others, like CATEC (Advanced Center for Aerospace Technologies) or AIMPLAS (Plastics Technology Centre) are focused in the development of technologies related with a specific sector or material. It is also worth mentioning the advanced 3D printing hub created in Catalonia with an investment of 28M€ and the direct collaboration of research centres and top companies in the area, such as HP, RICOH and Renishaw.

[7]

2. Germany

On this section of the report it will be briefly described the results of the focus group meetings conducted in Germany. The chapter is separated into four topics, considered most relevant for the analysis conducted on this report on AM.

2.1 Companies fit in the sectors

Table 4 Companies' Sectors

Sectors	Companies
1. Aerospace	Voestalpine Additive Manufacturing Center GmbH - (Düsseldorf, DE)
2. Automotive	Voestalpine Additive Manufacturing Center GmbH - (Düsseldorf, DE)
3. Industrial Equipment and Tooling	Deutsche Bahn AG - (Berlin, DE) Voestalpine Additive Manufacturing Center GmbH - (Düsseldorf, DE)
4. Railway	Deutsche Bahn AG – (Berlin, DE)

2.2 Companies fit in the value chain

Table 5 Companies' Value Chain

Companies	Value Chain					
	Modelling & Design	Materials	Process	Post-Processing	Product	End of Life
Stratasys	X	X	X	X	X	
Deutsche Bahn AG			X	X	X	
Voestalpine Additive Manufacturing Center GmbH	X	X	X	X	X	

2.3 Evidences from the focus group meetings

Table 6 Focus Groups Results

ORGANISATION	STRATASYS (RHEINMÜNSTER, DE)	DEUTSCHE BAHN AG (BERLIN, DE)	VOESTALPINE ADDITIVE MANUFACTURING CENTER GMBH (DÜSSELDORF, DE)
4. Main sectors served	industrial equipment and tooling	railway	aerospace, automotive, industrial equipment and tooling
5. Strategic relevance of metal AM for your main sector(s).	<p>Our company produces machines, equipment, materials in the field of AM.</p> <p>We are also supporting and offering services in the field of AM.</p>	<p>The Deutsche Bahn AG is a huge company in Germany and we are supporting this technology. We as the Deutsche Bahn are using AM to increase the availability of spare parts. We are working together with project partners, which produce for us. We have a huge network which is relevant for AM.</p>	<p>High importance, due to new business opportunities in a new market. AM shows the innovation force of our mother company.</p>
6. Is the creation of a European Qualification System in metal AM relevant for the sector(s)?	<p>Believe that a European Qualification body is mandatory.</p> <p>Our company is supporting students from the University Duisburg but we truly believe that there is high potential in the field of professional education.</p>	<p>YES!</p> <p>In the context of “Mobility goes Additive” the working group “Education” is also dealing with the topic how education in the field of AM could look like. We also released a first draft.</p> <p>The development of standards is always important.</p>	<p>First short view: Not really relevant, as we get qualified employees out of our network.</p> <p>Long term: Definitely, as standards and trust in production can only be achieved by know-how and qualification.</p>

These three companies represent the sectors, which are important for AM in Germany.

- industrial equipment and tooling
- automotive
- aerospace
- railway

Furthermore, can be seen that the sector of education and training is growing.

2.4 Further relevant information

The second Additive Manufacturing Forum in Berlin took place on the 5th March 2018. The aim of the conference and exhibition was to highlight the perspectives of Additive Manufacturing for production and logistics, to network partners, to promote serial application and, most important, to answer questions on implementation. The common effort was an exchange between the industries: aerospace, automotive, railways, mechanical engineering, medical technology and science. Some of the important branches/sectors featured in the Forum were:

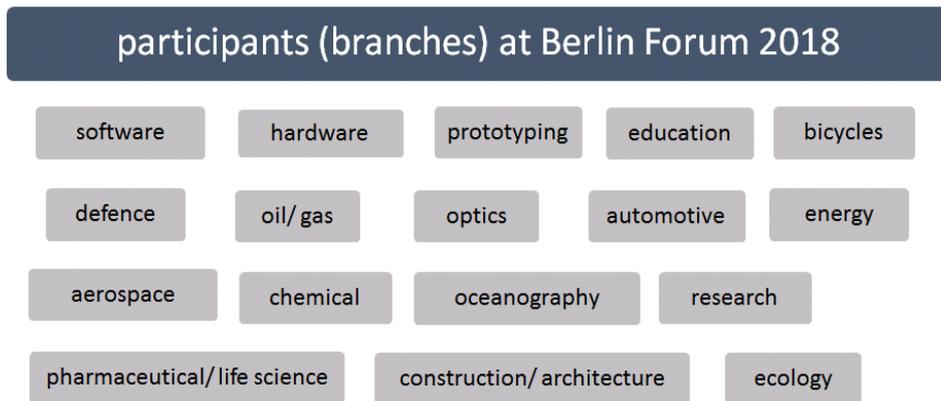


Figure 9 Participants at Berlin Forum 2018 [8]

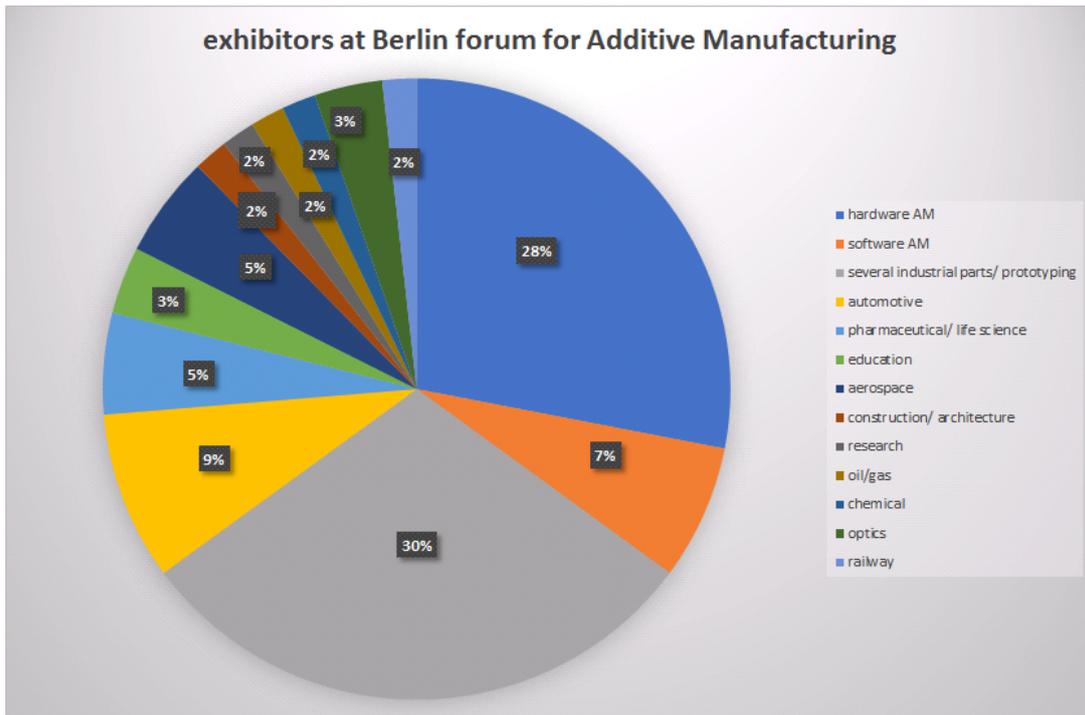


Figure 10 Results from Berlin forum for Additive Manufacturing [9]

Responding to the growing interest on AM in Germany several sectors are using Additive Manufacturing:

Table 7 Relevant Sectors for Additive Manufacturing in Germany

Important sectors (International)	Important sectors (Germany)
<ul style="list-style-type: none"> • Consumer products • Automotive • Aerospace • Medical 	<ul style="list-style-type: none"> • Prototyping • Hardware/Software • Aerospace/ Defense • Automotive • Railway • Medical
<p>These sectors are for metal and plastic</p>	

The job market in Germany correlates with the market share of additive manufacturing regarding:

- Construction and mechanical engineering (not considered because of equipment manufacturers)
- Automobile
- Medicine
- Aerospace

3. United Kingdom

On this section of the report it will be briefly described the results of the focus group meetings conducted in United Kingdom. The chapter is separated into four topics, considered most relevant for the analysis conducted on this report on AM.

3.1 Companies fit in the sectors

Table 8 Companies fit in the sectors

Sectors	Companies
1. Aerospace	HiETA Technologies - (Bristol, UK) 3T-RPD - (Newbury, UK)
2. Health/Medical	Orchid Orthopaedics (UK) Smith & Nephew (UK)
3. Automotive	3T-RPD - (Newbury, UK)
4. Consumer Goods	3T-RPD - (Newbury, UK)
5. Energy (Oil & Gas)	Baker Hughes – GE - (Aberdeen, UK)

3.2 Companies fit in the value chain

Table 9 Companies fit in the value chain

Companies	Value Chain					
	Modelling & Design	Materials	Process	Post-Processing	Product	End of Life
Not Applicable	NA	NA	NA	NA	NA	NA

3.3 Evidences from the focus group meetings

Table 10 Evidences from focus group meetings

ORGANISATION	HIETA TECHNOLOGIES (BRISTOL, UK)	3T-RPD (NEWBURY, UK)	BAKER HUGHES – GE (ABERDEEN, UK)
1. Main sectors served	<p>Primary markets: Energy, Motorsport, Aerospace & Defence.</p> <p>Secondary: sporting goods, industrial equipment & automotive</p>	<p>Primary markets: Aerospace, automotive</p> <p>Secondary: consumer electronics, industrial equipment & tooling, energy, marine & offshore</p>	<p>Primary markets: Oil & Gas</p> <p>Secondary: Aviation, Power, Digital Medical (as part of GE European Council & the AM Board)</p>
2. Strategic relevance of metal AM for your main sector(s).	<p>As a company who specialises in metal AM products & services the process is central to our strategic direction. We have developed and continued to develop an IP and product portfolio of designs/applications specifically for metal AM processes and the process is critical to achieve the benefits in our current and target applications.</p>	<p>AM is opening up products and parts which could not be made by other means; therefore, it is allowing companies that adopt AM to get strategic advantage over other existing products in these sectors (aerospace & automotive).</p>	<p>GE owns 2 metal AM machine companies and we have global research centres developing AM parts & processes. You also need to consider non-metallic as we are setting up a Centre Of Excellence for non-metallic in Aberdeen (investment secured from the Scottish government, which is an indication of the strategic relevance in Oil & Gas)</p>
3. Is the creation of a European Qualification System in metal AM relevant for the sector(s)?	<p>Believe that if a common training programme and qualification level was implemented it would support the growth of the industry and acceptance of AM in these sectors.</p>	<p>All sectors are looking for recognised standards and controls to allow them to identify which suppliers can produce production parts in a qualified way. Any standard or qualification which will achieve this will be useful.</p>	<p>Yes, but again also include non-metallic. We have developed training courses already that are applicable for Designers, which includes metallic and non-metallic. We used an external company which put this together for us. A formal qualification program would definitely be of interest to all our sectors in GE</p>

3.4 Further relevant information

Orchid Orthopaedics

The strategy is to service the medical implant industry with high quality implants. Additive manufacturing is changing the way implant manufacturers look at design improvements. Whilst the core manufacturing processes (casting, forging, coating etc.) remain, additive manufacturing will open new opportunities to improve the design of existing products and will play a role in future developments within the industry.

Orchid specialises in medical implant supply to various companies within the medical industry. The use of additive manufacturing has opened new concepts of design for medical implants and devices. A typical example of this is the process of applying a porous structure to implant sections which need to fuse with the surrounding bone structure. Previously this was applied as a coating but AM is allowing this to be added directly to the required surface as one complete continuous porous structure. Additional possibilities include precision made implants based on MRI and CT scanning technologies and using additive manufacturing via 3D modelling to precisely surface build to a specific patient's unique joint profile.

For the industry to have confidence in these processes and access to the technology grows it is essential that those involved in the process are accredited in some way through certification. However, time and costing needs to be reasonable to the user and specific to our application needs.

Smith & Nephew

Strategically we see additive manufacturing as a growth market within the medical device industry. It closely links with design improvements but a service within health that allows devices such as implants to be supplied to exact patient requirements within a set agreed time frame ready for actual implantation. This starts from patient assessment to 3D design, transfer of design data to the manufacturing process then implant supply back to the hospital.

Additionally, we have the possibility to rapid prototype new design ideas.

Overall additive manufacturing will become an integral part of the future manufacturing process within the medical industry.

We need to be confident there is a path of education and certification for the future professionals within additive manufacturing. A qualification body needs to be in place for this industry sector. How that will function needs to be well thought out.

Additional remarks

A series of interviews were conducted with various companies in UK and it was possible to observe a significant increase in interest and activity within the Oil & Gas sector, although aerospace & medical still dominate the AM landscape.

Section III – Comparison Between Consortium Countries and European AM Market

Researches conducted by the CLLAIM Consortium confirmed the increasing use of Additive Manufacturing technologies in several industry sectors in Europe and worldwide. AM technologies bring undeniable assets and redefine manufacturing in terms of modernity and efficiency. Several benefits of Additive Manufacturing can be highlighted, namely regarding time and energy savings, reduction of waste production, better opportunities in terms of mass production, production delays and quality standards, as well as more and more flexibility and liberty related to production processes and conditions.

To complete this report, it was used data collected within the research conducted by Partners as well as the valuable information provided in the “European Technology Platform in Additive Manufacturing” given a panorama of more than 400 European companies linked to the additive manufacturing sector.

For a better understanding of the AM market was conducted an extensive research in order to sort out some key aspects regarding this market. The results here illustrated concern with the analysis of AM market in Europe and Consortium countries sorted out by sector, value chain, processes used and materials. Moreover, it was also conducted a research on the relation between the previous stated variables.

The analysis of the AM market is relevant to the project as it enables a better understanding of the qualification system under development.

Starting by the analyses of the AM sectors, was developed a graphic identifying the percentual coverage of each sector European wide, as it can be seen below.

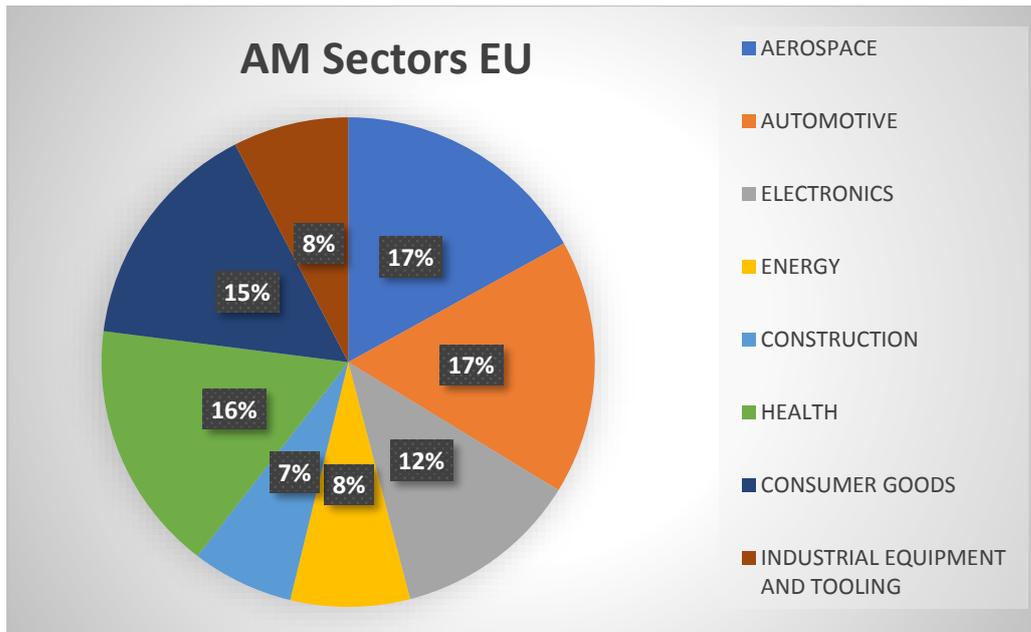


Figure 11 EU AM Sectors, *European Technology Platform in Additive Manufacturing*

We can observe that some of the sectors with the higher demand regarding the use of AM technologies are the aerospace and automotive sectors, followed by health and consumer goods.

Thereafter, was conducted the same analysis, this time for each partner’s country. The result is exhibited on the following graphics.

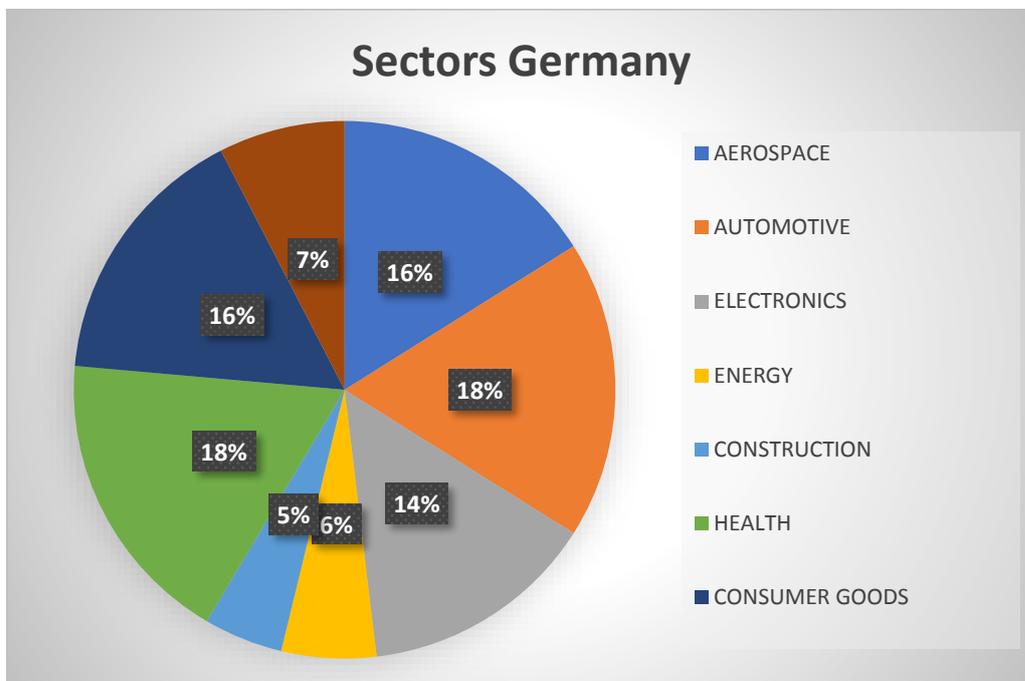


Figure 12 Germany AM Sectors, *European Technology Platform in Additive Manufacturing*

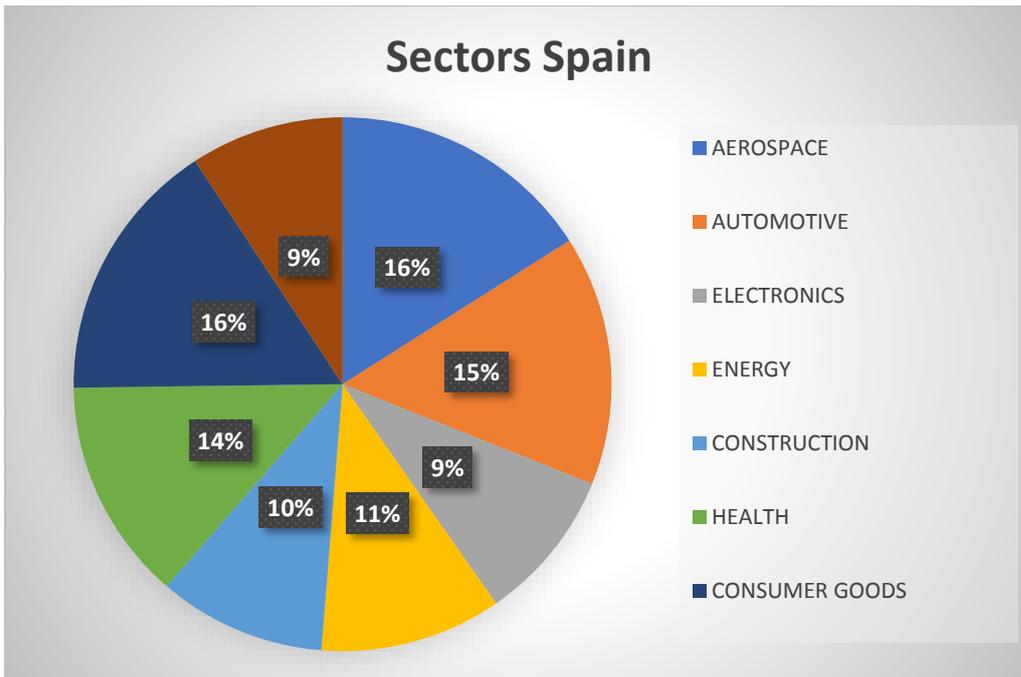


Figure 13 Spain AM Sectors, *European Technology Platform in Additive Manufacturing*

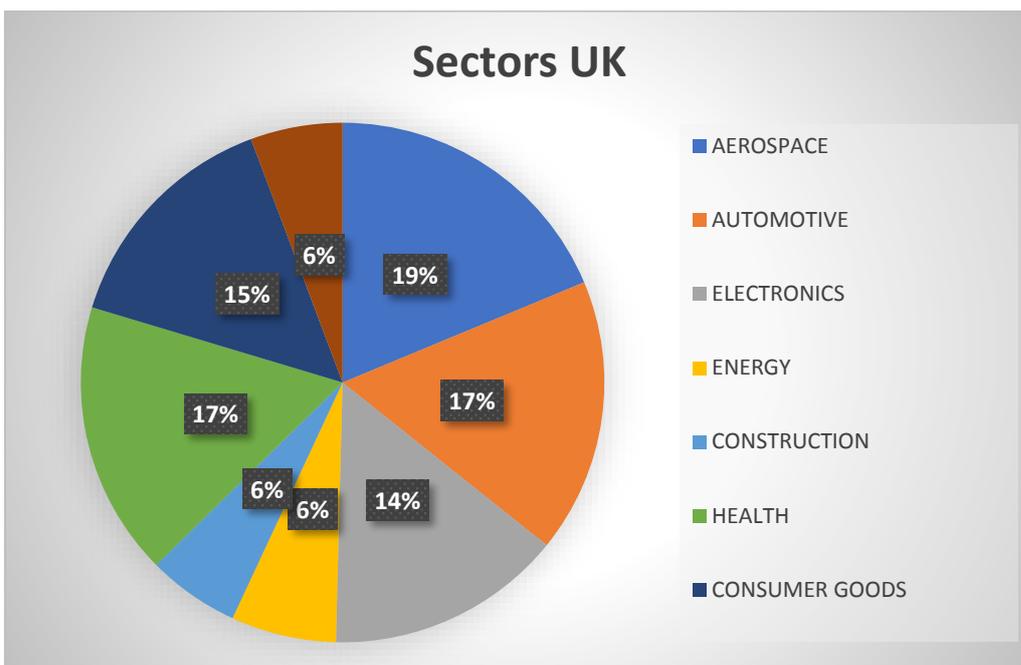


Figure 14 United Kingdom AM Sectors, *European Technology Platform in Additive Manufacturing*

From the results of these graphics can be understood that in Spain and in UK, there is an increasing interest for AM in the energy sector, whereas in Germany consumer electronics and Industrial equipment and tooling have a higher demand. Being the most relevant sectors, for all consortium countries, the Aerospace and Automotive.

While comparing the graphics from partner’s countries with the European ones we conclude there is a very high similarity on how AM is distributed through sectors in those

countries. The variations from partners countries and European average values don't overcome the 3 percentual values and results can then be summarized by the European ones. Because of this similarity, afterwards when comparing variables, the European variables will be considered. Moreover, EU values are more statistically reliable, as they cover more entities than single country values.

Secondly, was done an analysis of the AM Processes relevance for Europe and project partner's countries.

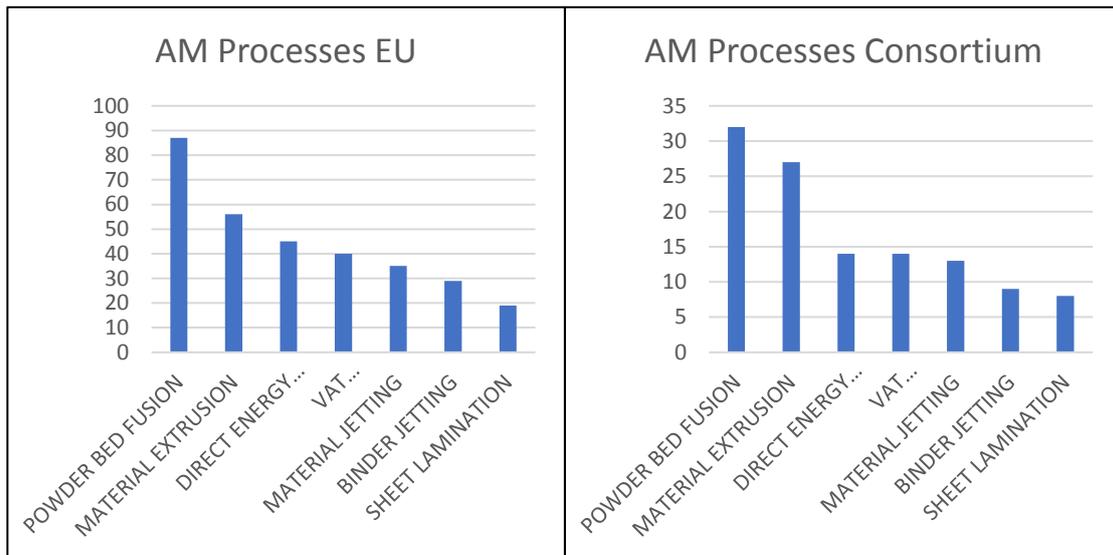


Figure 15 AM Processes, European Technology Platform in Additive Manufacturing

There can be identified a close relation between European and Consortium countries values. Although this similarity is not as identical as for the AM sectors, it is still enough to consider European values in future analysis. This issue with the similarity is due to the small amount of values collected on Consortium countries, therefore European data is considered more reliable.

While looking at the data can be concluded that the processes with more coverage amongst Europe are: Powder Bed Fusion (PBF), Material Extrusion and Direct Energy Deposition (DED). Furthermore, partners agreed that PBF and DED will be the processes covered on the project, for each one of the profiles addressed at the beginning of this report (Operator, Designer, Inspector and Specialist). This decision was done in accordance with all partners, due to the objective to ensure that the most relevant processes for Metal AM are covered.

Thirdly, it was analyzed the behavior of the Value Chain for the AM market. The graphics below illustrates the information featured in the “European Technology Platform in

additive Manufacturing” regarding the value chain in additive manufacturing for Europe and Consortium Countries.

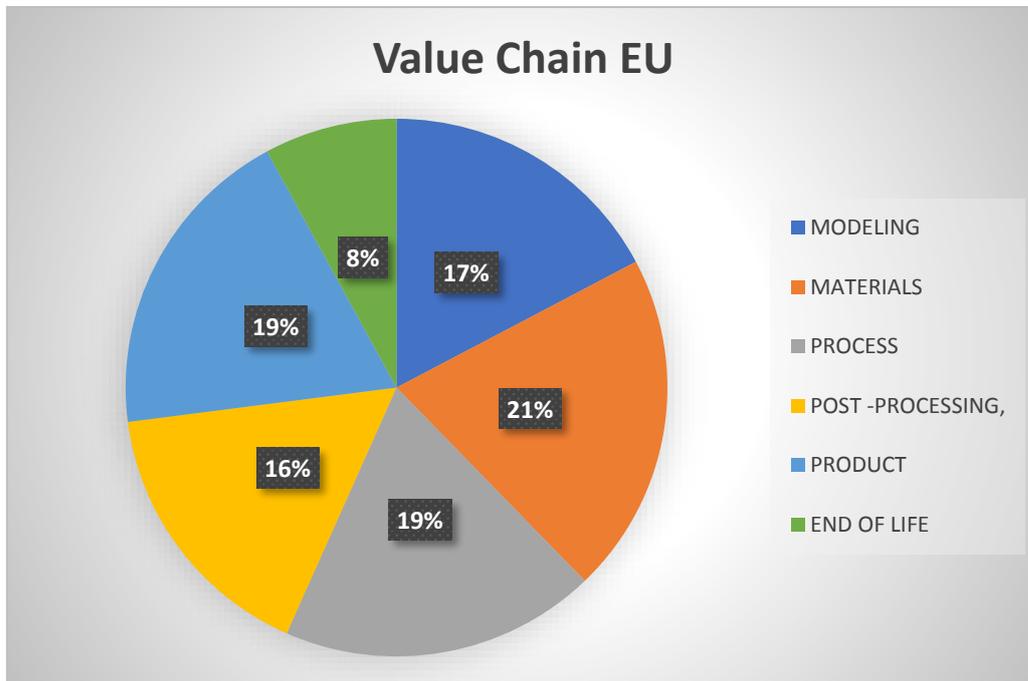


Figure 16 AM Value Chain Europe, *European Technology Platform in Additive Manufacturing*

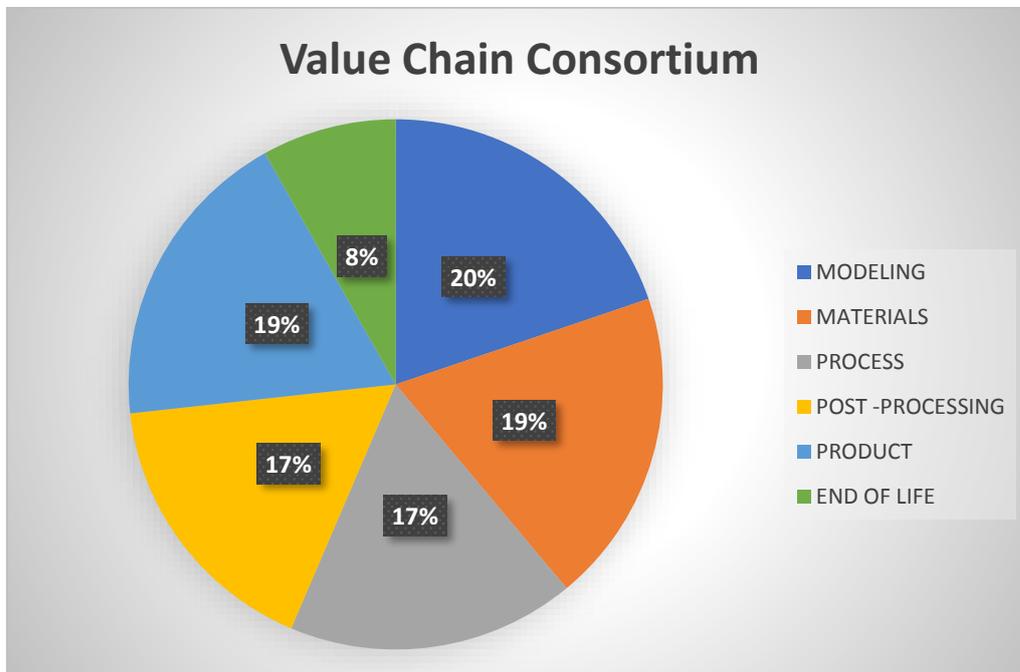


Figure 17 AM Value Chain Consortium Countries, *European Technology Platform in Additive Manufacturing*

From the analysis of the graphics above, can be concluded the Value Chain behaves almost identically for Europe and Consortium countries. Furthermore, that some of the

most evocative fields of expertise in the additive manufacturing sector can be linked to materials (21%) as well as process (19%), products (19%) and modeling (17%). In further analysis, European data will be considered as it is more statistically reliable, due to the amount of results.

The final variable to be taken under project consideration is Materials used on Additive Manufacturing. From the same data as the previous variables the graphic below was developed.

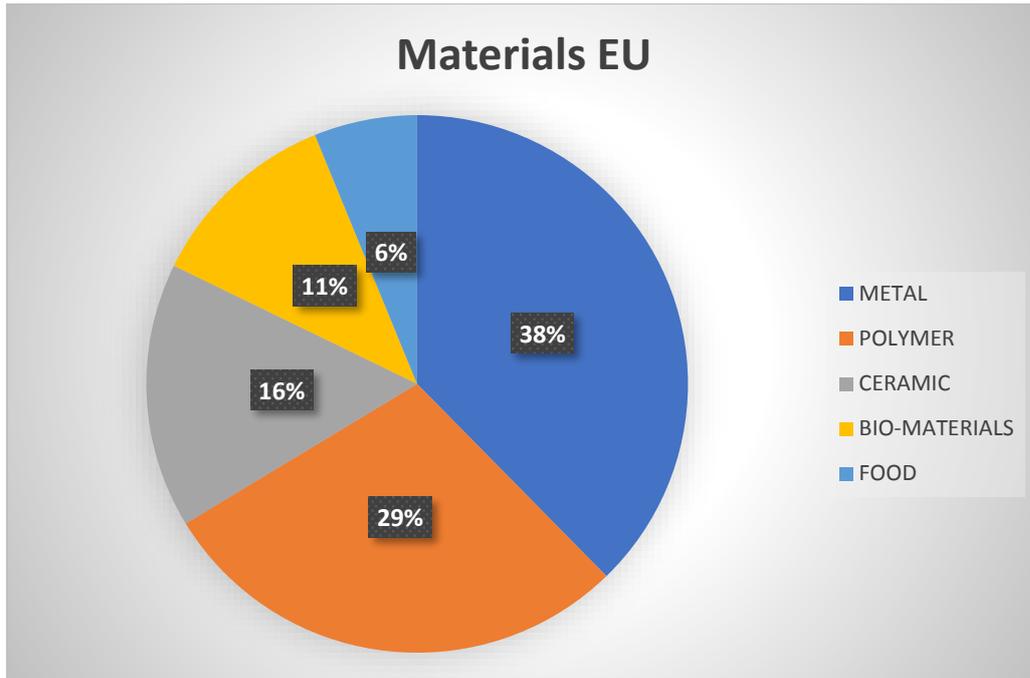


Figure 18 AM Value Chain Consortium Countries, European Technology Platform in Additive Manufacturing

By analyzing this graphic, we can observe that the most common materials on AM are ranked by Metal, Polymer, Ceramic, Bio-Materials and Food. Further in the report this variable will be associated with other variables so that a detailed analysis can be conducted.

After a characterization of the variables that drive the AM market some relationships will be highlighted in order to develop the Knowledge on Additive Manufacturing.

First relation to consider is Value Chain per Sector. This relation will explain how value chain behaves for each of the major sectors encountered. The graphics below show this

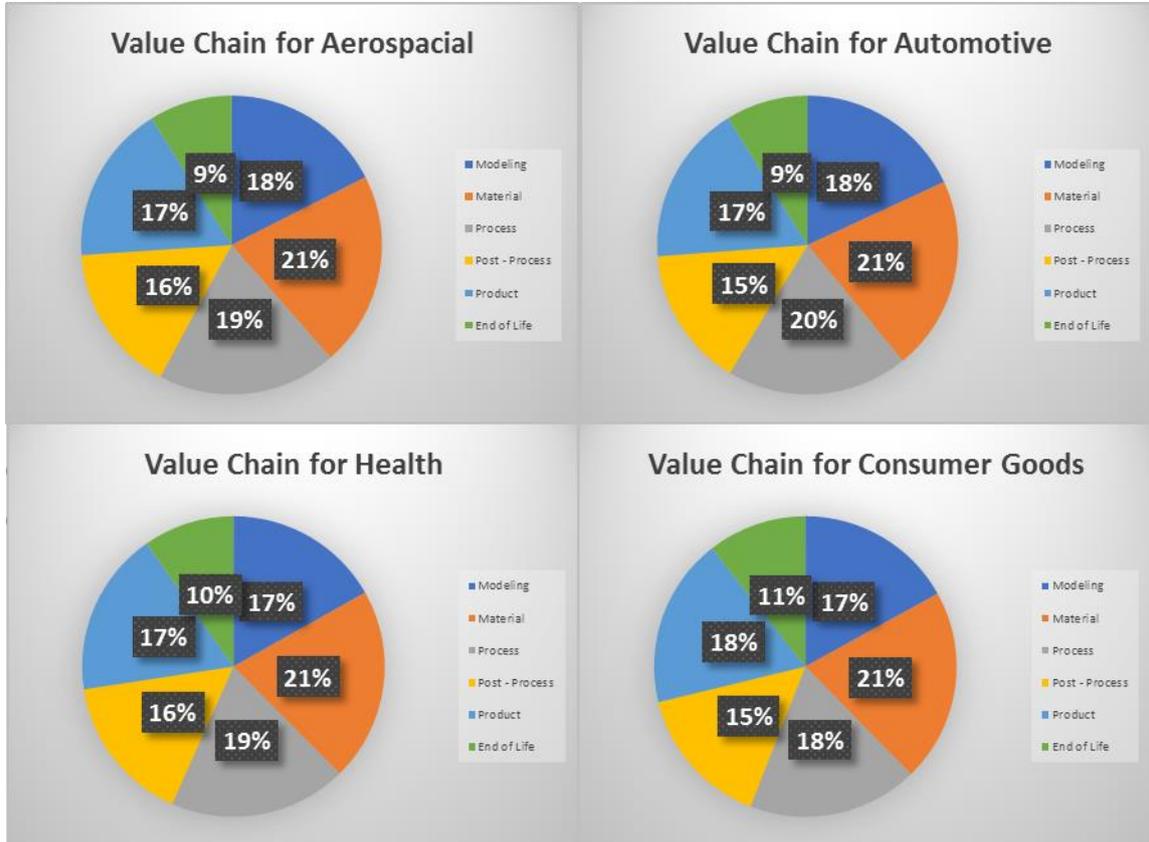


Figure 19 Value Chain per Sector, *European Technology Platform in Additive Manufacturing*

Second relation to be analyzed is between AM processes and Sectors. This will tell how the processes are spread in the different sectors. The graphics for this comparison the graphics below were developed.

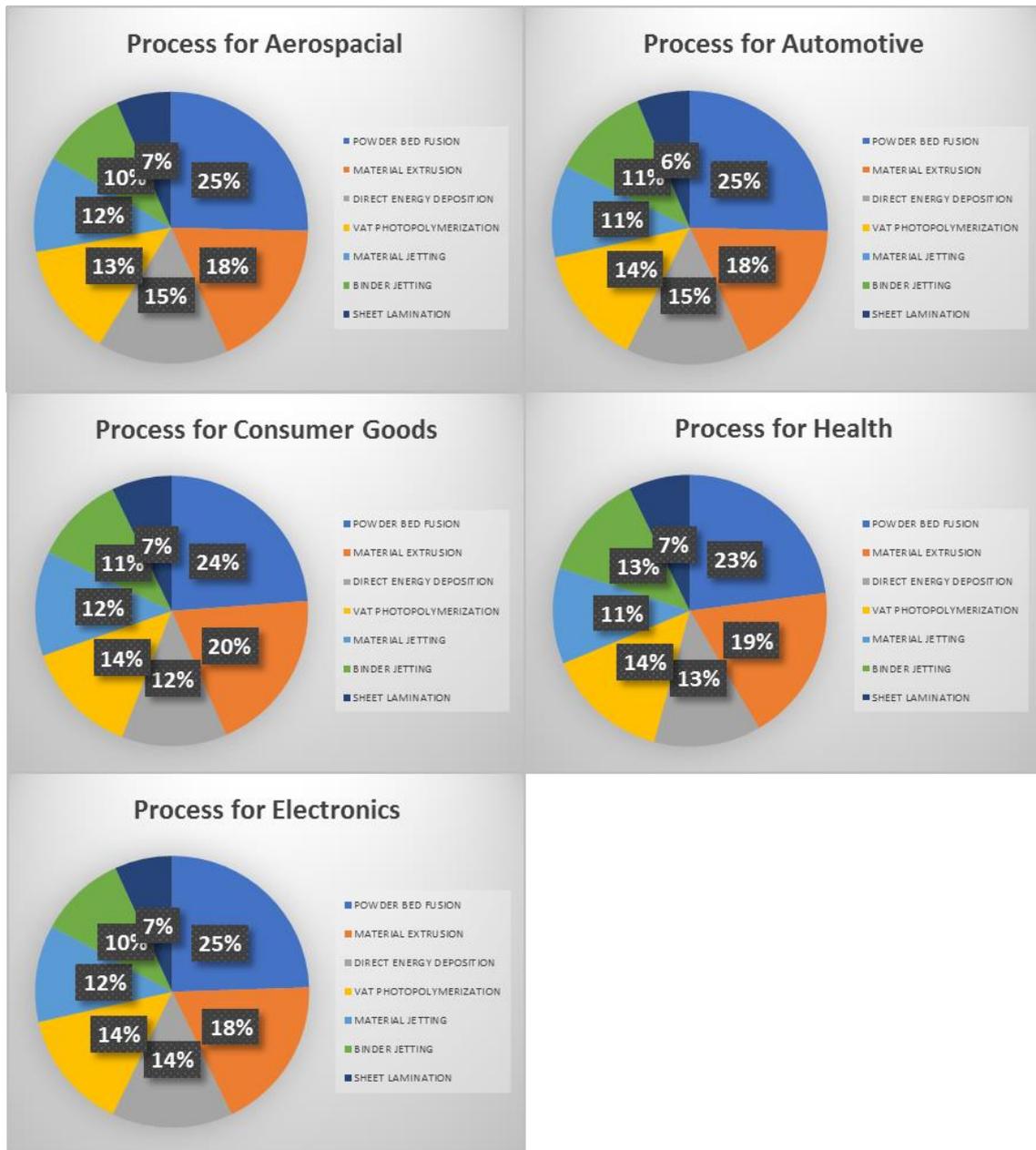


Figure 20 AM Processes per Sector, *European Technology Platform in Additive Manufacturing*

After observing this graphics, no major conclusion is reached, as they all behave similarly. Which means that no process is more used in a sector than in other. So, the only conclusion is that AM Processes behave independently from the sectors. Focusing on the two main sectors Aerospace and Automotive we observe that PBF has 25% and DED 15%, being these processes the ones CLLAIM project intends to tackle.

Besides relating variables with the sectors, it is also highlighted the relation between Value Chain and the Materials used in Additive Manufacturing. The graphics below show

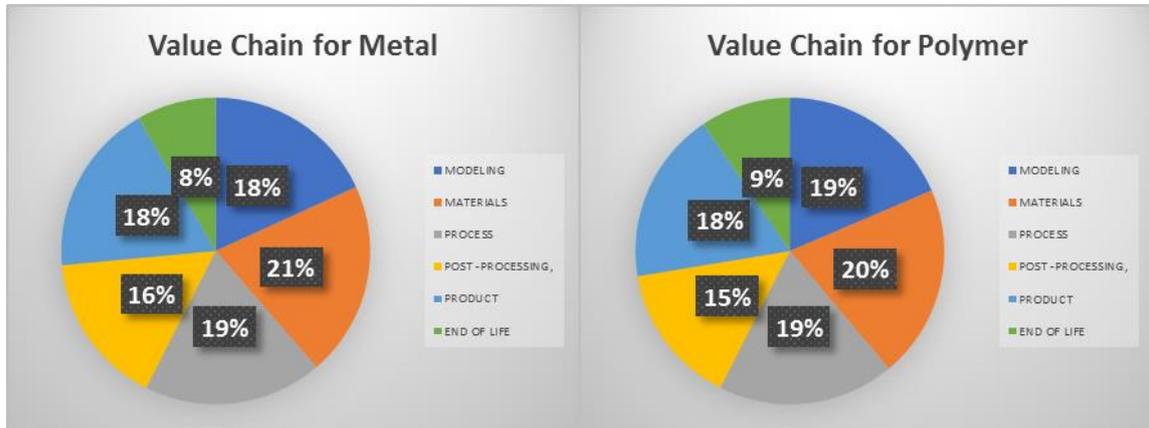


Figure 21 Value Chain for Metals and Polymers, *European Technology Platform in Additive Manufacturing*

this relationship.

For the two most relevant materials in AM it is concluded that there are no significant changes in terms of Value Chain that is addressed by the entities on the European Technology Platform in Additive Manufacturing database. By being very similar to the overall market behavior it means that we can treat Metal and Polymer equally to the generality when addressing value chain variable. Being CLLAIM project focused on Metal we can withdraw the conclusion that in the future if it is decided to extend the Qualification System to Polymers the necessity of the profiles will be very similar as the variable more connected with those profiles is value chain, although it is understood that the profiles may change. Moreover, the results of the value chain are considered to be decisive for the development of the contents for the Competence Units for the different job profiles within CLLAIM project.

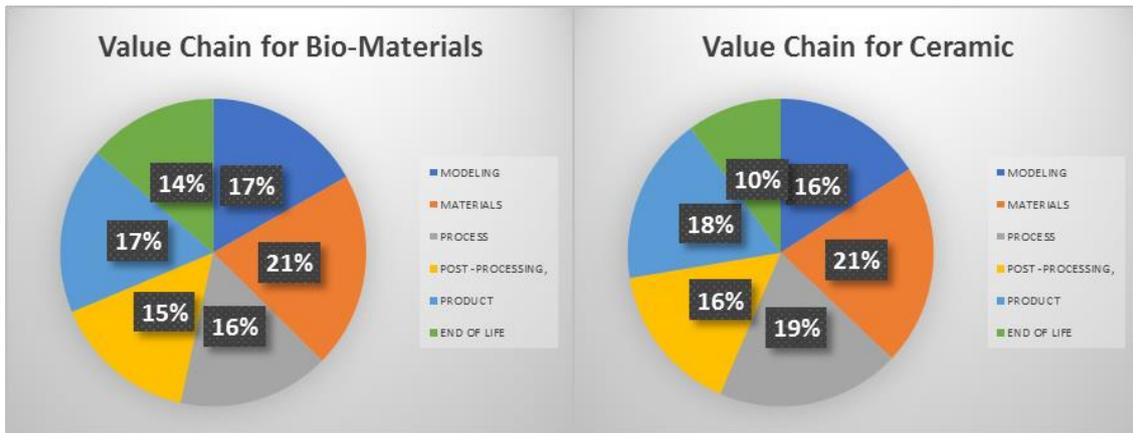


Figure 22 Value Chain for Metals and Polymers, *European Technology Platform in Additive Manufacturing*

While considering the two remaining materials, some discrepancies are observed. In terms of End of Life there is a small increase when compared to overall market, being more significant in bio-materials. Moreover, for bio-materials, there is also a small reduction when addressing process in the value chain. The remaining aspects of the value chain are similar to the generality of European values.

Finally, the last relation between variables that is analyzed is the Materials used for each AM Process. At this point, it is only addressed the most used AM processes in the industry: Powder Bed Fusion (PBF), Material Extrusion, Direct Energy Deposition (DED) and VAT Photopolymerization as they are the most relevant for this project. Furthermore, would also point out that this variables relation is the one with more significant results.

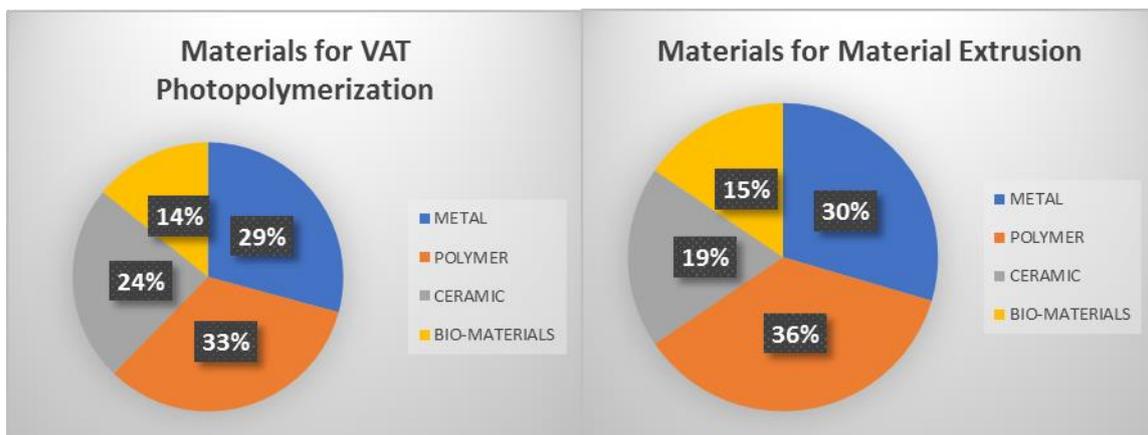


Figure 23 Materials for VAT Photopolymerization and Material Extrusion, *European Technology Platform in Additive Manufacturing*

While considering the graphics above we can observe that the two processes are more used for polymer materials, because of the intuit of this project is to focus on developing

skills and professional profiles for Metal AM, the two processes were disregarded. Thereafter, the following processes are the ones that most concern to the project.



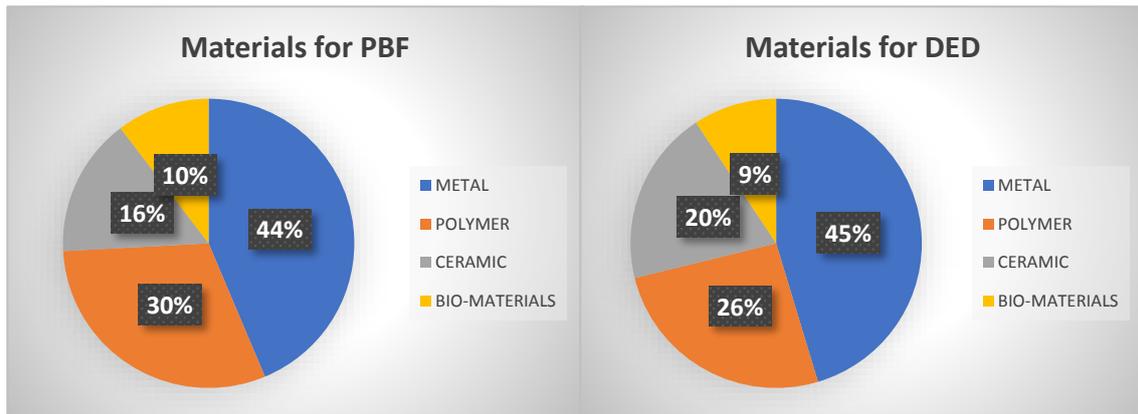


Figure 24 Materials for Direct Energy Deposition and Powder Bed Fusion, *European Technology Platform in Additive Manufacturing*

By analyzing these two graphics we can observe a close relation between the two processes in terms of materials. These two processes are more focused on metals, and this will be the main target of the qualifications developed further in the project. With the graphics above (Figure 29) the consortium verified a previously acquired knowledge that the two main processes categories used in Metal AM are PBF and DED, moreover by the graphics included on Figure 25 it is concluded that these two processes are the ones more used in metal AM industry (Representing around 40% of the market). These processes are subdivided into PBF – Laser Beam; PBF – Electron Beam; DED – Arc; DED – Laser Beam, and will be the ones considered in the scope of the Qualification System developed in CLLAIM project.

These extensive variables analysis concludes the comparison of the AM market between European and consortium countries. It is highlighted a very close relation between European and consortium values that allowed the comparison between the different variables conducted above.

Conclusion

The aim of CLLAIM project is to develop a Qualification System for Additive Manufacturing. Through an extensive market analysis, was concluded that the Additive Manufacturing industry in short term needs Qualifications for Metal and not for the remaining materials. Furthermore, there are 7 processes categories for Additive Manufacturing defined at ISO/ASTM 52900:2015: Powder Bed Fusion (PBF), Direct Energy Deposition (DED), Material Extrusion, Vat Photopolymerization, Material Jetting, Binder Jetting, Sheet Lamination. Partners agreed that will develop Qualifications only for PBF and DED. As these are the most relevant processes working with metals. This is confirmed by the results on section IV of this report.

This report on the Additive Manufacturing state of art started with a general view of the market behaviour along the world and then moved to Europe and detailed the knowledge in the consortium countries. The report concluded that AM is increasing exponentially along the entire world. Already occupies a significant role in several sectors and it is expected to keep increasing. Moreover, the report withdraws some conclusions that foster the development of the AM professional profiles lately in the project.

The first section of the report is a literature review on the state of art of AM market, aiming to give a general overview of the Additive Manufacturing sector and structure project future development. Through an analysis of AM landscape, it is verified the relevance of a Qualification System for Metal Additive Manufacturing. Still from the landscape analysis is concluded that CLLAIM project covers 53% of the companies' segments in AM, which are Post-processing, Metals, Metal Machines, Simulation Software and Design & CAD Software, being these areas the ones that interest CLLAIM professional profiles.

Additionally, in the Desk Research section is observed that AM market demand will double in the next 6 years, which supports the relevance of the project. Furthermore, it is observed that the two major sectors in AM are Automotive and Aerospace, although in this growing technology it is hard to understand if today's patterns will continue tomorrow, and some studies indicate a significative change on sectors balance, which alerts the partnership not to focus just on a specific sector. Also, it is identified that Consortium Countries are well positioned in the AM market, enhancing the relevance of the partnership. Another topic that stood out from the desk research is the need of

standards in AM and by so, it is identified the major necessity of aligning CLLAIM Qualifications with the upcoming ISO/ASTM standards for AM.

One of the main goals of the report was to evaluate the state of art of the AM market individually for each partner country. Therefore, focus group meetings were conducted and was reported a close analysis of Additive Manufacturing for Spain, Germany and United Kingdom. All the companies addressed in these events identified the lack of qualified personnel to use AM Technology and, consequently, the need of a Qualification System for Additive Manufacturing as a priority. The results of the focus group meetings boosted CLLAIM project's objective of creating a Metal European harmonized Additive Manufacturing Qualification System. Through this focus group meetings, the previous assumptions of the needs of an AM Qualification System and the relevance of AM in the consortium countries were validated, as all participants confirmed its importance. Some results are summarized hereinafter: European AM Qualification body is seen as a mandatory requirement that will certainly foster the development of AM and spread it among other industries; Several companies from the Aerospace sector shown the availability to adopt the Qualification System developed in CLLAIM project; Qualification System aligned with Standards is of most relevance to the AM sector. Again, is identified by several companies in the focus groups the need to address standardization in AM, participants believe that a Qualification System aligned with standards will foster AM implementation and Certification procedures on the Aerospace sector.

Finally, to conclude the report, was conducted a study on the variables that sustain the AM market. The most relevant variables are: Sector, AM Process, Value Chain and Materials. For all the variables was concluded that there is a very high similarity between European and consortium countries values, therefore partners can look at European level when developing CLLAIM Qualifications. While considering the variable "sectors", partners concluded that Aerospace is the most represented sector, and due to the bureaucratic obstacles in this sector, special conditions on the Qualifications are to be considered. Automotive, a well-known sector comes in second place. Although these two sectors are the most representative sectors, partners should not neglect the remaining sectors as it is predicted an inversion on sectors' balance in AM. Furthermore, while analysing the Value Chain for AM is concluded that CLLAIM profiles cover the Value Chain in its overall.

Moreover, was conducted a cross check between variables that concluded most of the variables behave independently from each other. Although when looking at the effect of AM processes on materials was validated a previous knowledge that for metal the most utilized processes categories are Powder Bed Fusion and Direct Energy Deposition, and these will be the processes that the consortium will develop qualifications for. While CLLAIM intends to develop Qualifications for Metal AM PBF and DED are the processes that majorly work with metallic materials. PBF has 25% and DED 15% of market share, which means that CLLAIM will tackle 40% of the market when considering AM processes.

Further, due to the close relation with the AM market and the evaluation carried out in this report the consortium considers fundamental that the Qualification System is built in a way that it can be extended to other areas besides Metal. This means that the system built is flexible enough to easily be adapted and improved in the future. One key foundation of this flexibility in the system is the development of Qualifications based on a Modular structure.

With this Report on AM the consortium defined the first steps and set the path for the development of a Harmonized Qualification System, which will be undertaken within WP3. CLLAIM project relevance is validated in all sectors as it covers around half of Additive Manufacturing market needs. On the remaining tasks of CLLAIM project the results here obtained are to be considered as a basis for the future developments, namely for the development of surveys.

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